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Vapour-Liquid-Solid State Cadmium Oxide Nanowires and Nanobelts

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ABSTRACT

Nanowires and Nanobelts were fabricated by simple spray pyrolysis technique using cadmium oxide (CdO). XRD were taken for measuring the crystalline size, d-spacing value and structure of the CdO nanowire and nanobelts. Cadmium and Oxygen were found by FTIR spectrum. Length of the CdO nanowire and nanobelts were photographed by using Scanning Electron Microscope.

Keywords: Nanowires, Nanobelts, Spray pyrolysis, SEM, CdO.

1. INTRODUCTION

Recent progress in the synthesis and characterization of Nanowires /Nanobelts has been driven by the need to understand the novel physical properties of one-dimensional nanoscale electronic and optoelectronic devices. Nanowires/ Nanobelts with different composition have been explored using various methods including the vapour-phase tranport process. Chemical vapor deposition, arc discharge, laser absorption, solution, and template based-method. While a large part of this work has been focused on semiconductor system such as Si, Ga, GaN, GaAs, only a few studies on Oxide system exist in the literature. Among them, MgO nanowires have been synthesized and incorporated into-high temperature superconductors to improve the critical current densities of the superconductors. Several other other Oxide nanowires, including SiO_2, GeO_2, and Ga_2O_3 have also been reported although the insulating nature of these Oxide systems could limit, if any, their applications. It is thus necessary to look into other Oxide system with interesting optical, electrical and magnetic properties. Zinc oxide nanobelts were prepared and reported[1].

CdO is a wide band gap (3.37eV) semiconductor with large exciton binding energy investigated as a short wave-length light emitting, transparent conducting and piezoelectric meterial. CdO nanoclusters and thin film have also been shows to exihibits room temperature UV lasing properties.

CdO is used as a transparent conductive material[2] which was prepared as a transparent conducting film back in 1907[3] Cadmium Oxide in the form of thin films has been used in applications such as photodiodes, phototransistors, photovoltaic cells, transparent electrodes, liquid crystal displays, IR detectors, and anti reflection coatings. CdO micro particles undergo band gap excitation when exposed to UV-A light and is also selective in phenol photo degradation[4,5].

Nanowires/Nanobelts are a nano-structure, with the diameter of the order of a nanometer (10^{-9} meters). Alternatively, Nanowires/Nanobelts can be defined as structures that have a thickness or diameter constrained to tens of nanometers or less and an unconstrained length. At these scales, quantum mechanical effects are important which coined the term "quantum dots". Many different types of Nanowires/ Nanobelts exist, including metallic, semiconducting and insulating.

Typical Nanowires/Nanobelts exhibit aspect ratios (length-to-width ratio) of 1000 or more. As such they are often referred to as one-dimensional (1-D) materials. Nanowires/ Nanobelts have many interesting properties that are not seen in bulk or 3-D materials. This is because electrons in Nanowires/ Nanobelts are quantum confined laterally and thus occupy energy levels that are different from the traditional continuum of energy levels or bands found in bulk materials. Peculiar features of this quantum confinement exhibited by certain Nanowires/ Nanobelts manifest themselves in discrete values of the electrical conductance. Such discrete values arise from a quantum mechanical restraint on the number of electrons that can travel through the wire at the nanometer scale.

Nanowires/Nanobelts may become important in electronic, opto-electronic and nano electromechanical devices, as additives in advanced composites, for metallic interconnects in nanoscale quantum devices, as field-emitters and as leads for biomolecular nanosensors.A common technique for creating Nanowires/Nanobelts is the vapour liquid-solid (VLS) synthesis method.

Nanowires/Nanobelts also show other peculiar electrical properties due to their size. Unlike carbon nanotubes, whose motion of electrons can fall under the regime ballistic transport (meaning the electrons can travel freely from one electrode to the other), nanowire conductivity is strongly influenced by edge effects. The edge effects come from atoms that lay at the nanowire surface and are not fully bonded to neighboring atoms like the atoms within the bulk of the nanowire. The unbonded atoms are often a source of defects within the nanowire, and may cause the nanowire to conduct electricity more poorly than the bulk material. As a nanowire shrinks in size, the surface atoms become more numerous compared to the atoms within the nanowire, and edge effects become more important.

To create active electronic elements, the first key step was to chemically dope a semiconductor nanowire. This has already been done to individual Nanowires/ Nanobelts to create p-type and n-type semiconductors.

The next step was to find a way to create a p-n junction, one of the simplest electronic devices. This was achieved in two ways. The first way to physically cross a

p-type wire over an n-type wire. The second method involved chemically was doping a single wire with different dopants along the length. This method created a p-n junction with only one wire.

It is possible that semiconductor nanowire crossings will be important to the future of digital computing. Though there are other uses for Nanowires/Nanobelts beyond these, the only ones that actually take advantage of physics in the nanometer regime are electronic.

Nanowires/Nanobelts are being studied for use as photon ballistic waveguides as interconnects in quantum effect well photon logic arrays. Photons travel inside the tube, electrons travel on the outside shell**..** The synthetic studies of multiple morphologies of CdO structures constitute tide basis for developing versatile application in the developed of new domains.

2. EXPERIMENTS

The CdO Nanowires/Nanobelts prepared by following technique Spray Pyrolysis technique is simple and inexpensive and hence requires less cost to prepare nanowires/nanobelts than other conventional techniques.

The Spray Pyrolysis technique involves stages like spraying a solution, usually aqueous containing soluble salts of the constituent atoms of desired compound on to a substrate maintained at evaluated temperature. The Sprayed droplet reaching the hot substrate surface undergoes Pyrolysis (Endothermic) decomposition and forms a single crystalline or a cluster of crystallites of the product. The other volatile by products and the excess solvent escape in the vapor phase.

The chemicals used for Spray Pyrolysis have to satisfy the following conditions:

On thermal decomposition the chemicals in solution from must provide the species/complexes that will undergo a thermally activated chemical reaction to yield the desired thin film material. Spray Pyrolysis method has series of advantages over other techniques. These can be summarized as follows:

1. Low cost equipments
2. Large area coating
3. Time saving method
4. Strong additive with substrate

The control parameters in the Spray Pyrolysis method are the temperature of the substrate, the solution composition, the carrier gas solution flow rate, the deposition time, the nozzle to substrate distance and angle. Conventional Spray Pyrolysis set up essentially consists of four major parts. They are Spray gun, Solution.,Carrier gas and controlling derive with pressure gauge Substrate temperature latch with controller and measurement device. Cadmium chloride dissolved with water and stirred using magnetic stirrer till get a transparent solution. The transparent solution and compressed air are released through a fine spray gun nozzle. During spray process fine droplets passed through nozzle divided into so many finest droplets and these are falling over glass plate which is kept on the hot plate. After taking the glass plate from the furnace, it is allowed to cool for few minutes and final CdO nanowire/ nanobelt were obtained.

The well prepared CdO Nanowires/ Nanobelts structure were analysed by

X – Ray diffraction[XRD PAN analytical – Make, X per PRO-model employing copper K alpha beta radiation]. XRD is a very powerful tool in the study of solid state materials. The uniqueness of thin technique is that it is non-destructive and furnishes multiple results inching crystal lattice details down to the atomic level.

From the geometrical considerations the basic Bragg equation is formed as $2d\sin\theta = n\lambda$, where d is the inter plan distance (or lattice constant), is the wavelength of the characteristic X – rays and 2θ is the angle between the diffracted beam and the transmitted beam and n is the order of the scalded beam. This famous Bragg's law provides the basic platform for the XRD methods from this law, the inter planer distance can be calculated.

In crystalline solids, all the atoms in the path of the x ray beam scatter the X ray simultaneously. In general, the scattered waves interface and destroy one another's, but in certain specific direction (20), they combine to form new ware – fronts, this co-operative scattering is known as diffraction and instruments that are used to study the diffraction suitable for the study of polycrystalline are called X – ray power diffractometers. A diffracted beam may be defined as a beam composed of a large number of scattered rays mutually reinforcing another.

The effect of line broadening is primarily due to the micro – residual stress and particle size. In case of negligible micro – residual stress (and instrumental broadening) the particle or crystalline size (D) is computed from.

$$D = 0.9\,\lambda/\beta\cos\theta \qquad (2.1)$$

Where, β is the broadening of the line measured at half its minimum integrity in lattice (F WHM – Full – Width at half - Maximum).

Once the crystallite size is estimated, the number of crystalline per surface area can be obtained as,

$$N = (t/D^3) \qquad (2.2)$$

Where D is the mean crystalline size and t is the deposit thickness.

Dislocation density is calculated by using the

$$\delta = 1/D^2 \qquad (2.3)$$

The strain is calculated by employing the

$$\epsilon = \beta \cos\theta/4. \qquad (2.4)$$

Fourier transform infrared spectroscopy (FTIR) - is a technique which is used to obtain an infrared spectrum of cadmium oxide nano particles [thermo electron corporation-make, NEXUS 670-model].

FTIR spectrometer collects spectral data in a wide spectral range. From these spectroscopy presence of Cd and O were analysed in the CdO nano wires /nanobelts.

The morphology of the Nanowires/ Nanobelts was examined by scanning electron microscope [HITACHI-MAKE, S-3000H, SEM-MODEL]. The applied voltage for getting secondary electron is 20KV and working distance of 17.4 mm and magnification power is X25K and scale used for length from 0μm to 20μm.

3. RESULTS AND DISCUSSION

Spray pyrolysed technique used to synthesis nanowire/nanobelt. By changing various parameters like substrate to spray gun distance, solution concentration,

substrate temperature, spray gun diameter, air pressure fine nanowire /nanobelt are synthesized.

The SEM picture of the Nanowires/ Nanobelts in a particular position of the sample are taken at various magnification that is 20µm,10µm and 5µm.

From the SEM figure (3.1).it is seen that CdO Nanowires/Nanobelts are synthesized using Spray Pyrolysis method. In the same picture CdO are spreading and then wires are extended with almost uniform diameter. And length of the Nanowires/Nanobelts constant value of 17.4mm.

In the SEM figure (3.2). The particular portion is very clearly focus and the structures are the Nanowires/Nanobelts are clearly photographed.

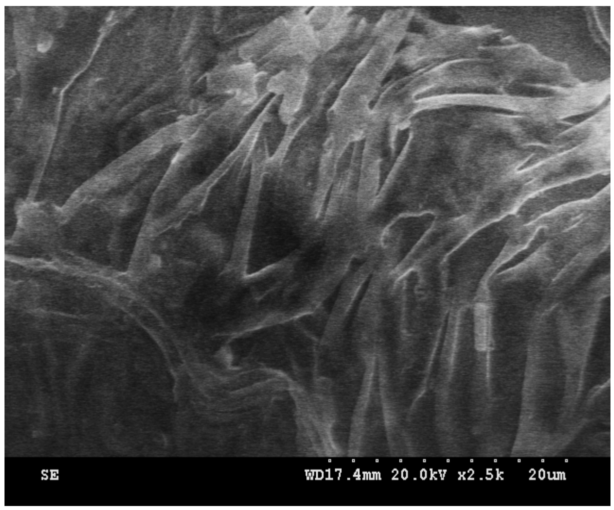

Figure 3.1.SEM image of CdO Nanowires/Nanobelts (X2 ,10 micrometer)

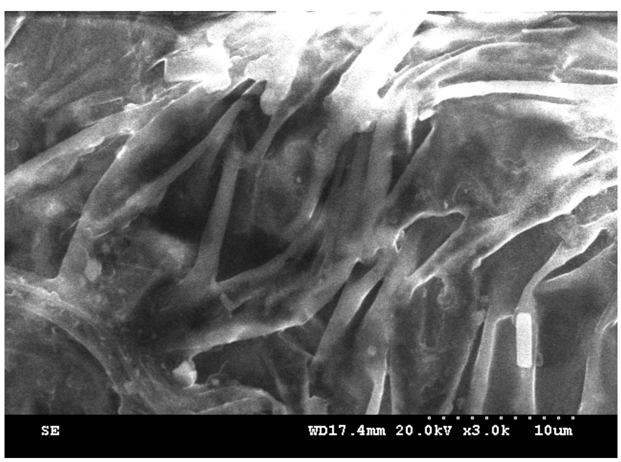

Figure 3.2.SEM image of CdO Nanowires/Nanobelts (X3 ,10 micrometer)

When we are very closed the SEM figure. It is possible to calculate the diameter of the Nanowires/Nanobelts and length of the Nanowires/Nanobelts. This is clearly seen in SEM figure in (3.3).

The Nanowires/Nanobelts length are varying from 16.8mm to 17.5mm per vertically. It is obtain from the SEM figure (3.4).

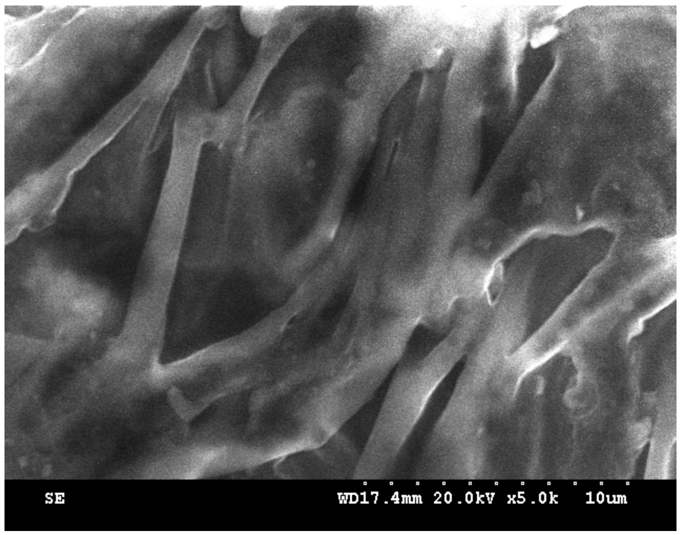

Figure 3.3.SEM image of CdO Nanowires/Nanobelts (X5 ,10 micrometer)

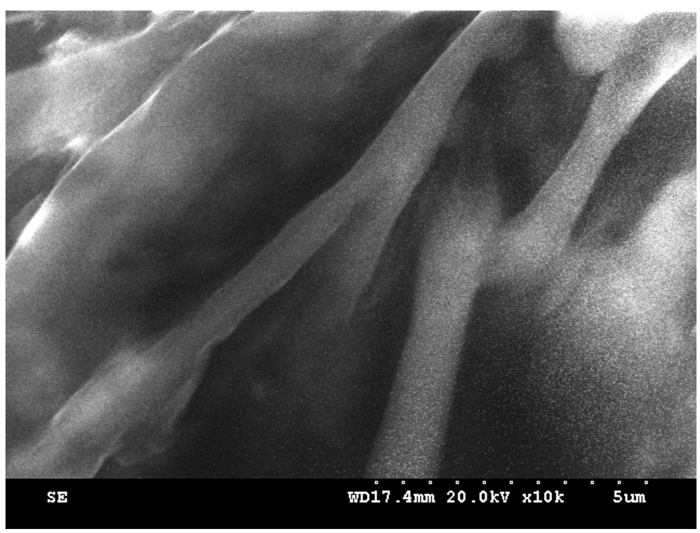

Figure 3.4.SEM image of CdO Nanowires/Nanobelts (5 micro meter)

The Spray Pyralysed CdO Nanowires/ Nanobelts have been structurally characterized by X-ray diffraction A typical XRD pattern of Nanowires/Nanobelts shows in figure (3.5).

If can be seen that the Nanowires/Nanobelts display the structure with high crystallinity compared with the standard diffraction patttern of CdO.

From the XRD spectrum it is seen that there will be three 2θ values 33.060, 38.403 and 69.303. and its corresponding peak heights are 446.93, 10.19 and 35.22 also the full width half maxima values are 0.4349, 0.8029 and 0.6528. The d-spacing values are 2.709, 2.344 and 1.354 for the above 2θ values respectively.1.3 for 33.060, 38.403 and 69.303 respectively.

The further peaks indicate the growth of Nanowires/Nanobelts. Addition peaks along with the main peaks shows the growth of Nanowires/Nanobelts [table3.1]

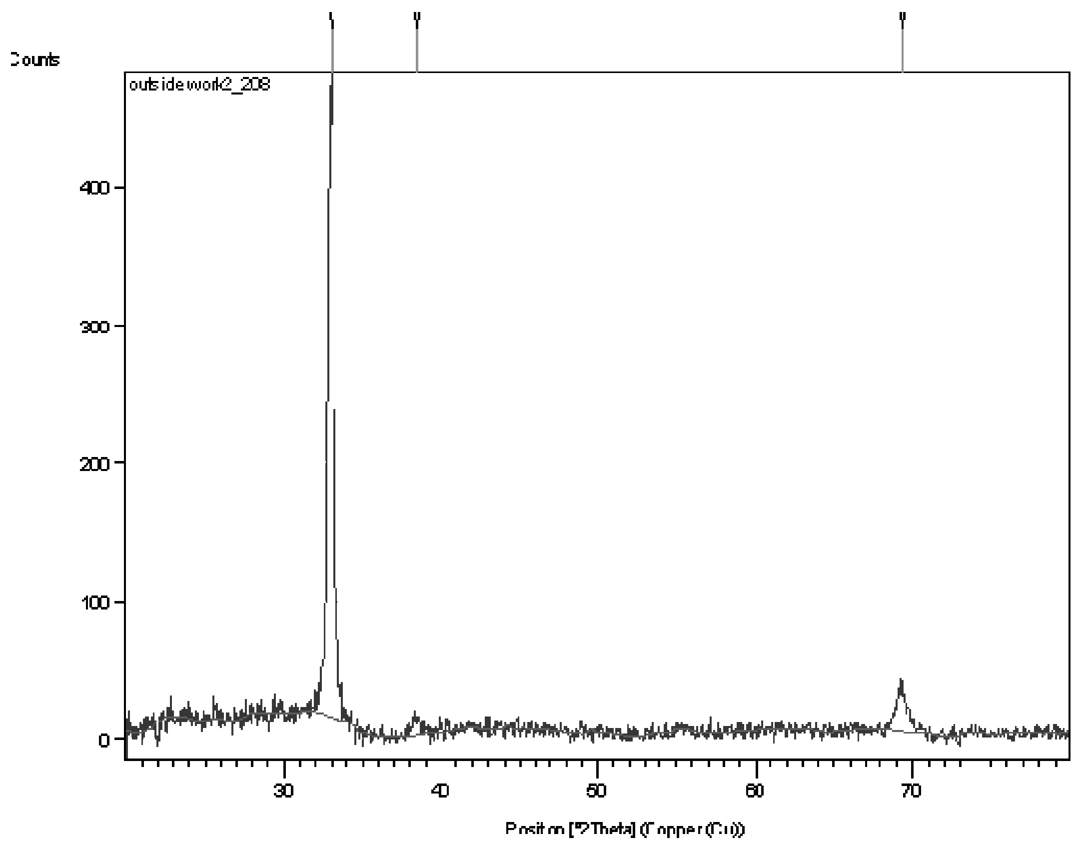

Figure 3.5. XRD pattern of CdO Nanowires/Nanobelts

Table: 3.1. D-spacing value of CdO Nanowires/Nanobelts

Pos. [°2Th.]	Height [cts]	FWHM [°2Th.]	d-spacing [Å]	Rel. Int. [%]
33.0606	446.93	0.4349	2.70959	100.00
38.4031	10.19	0.8029	2.34404	2.28
69.3037	35.22	0.6528	1.35476	7.88

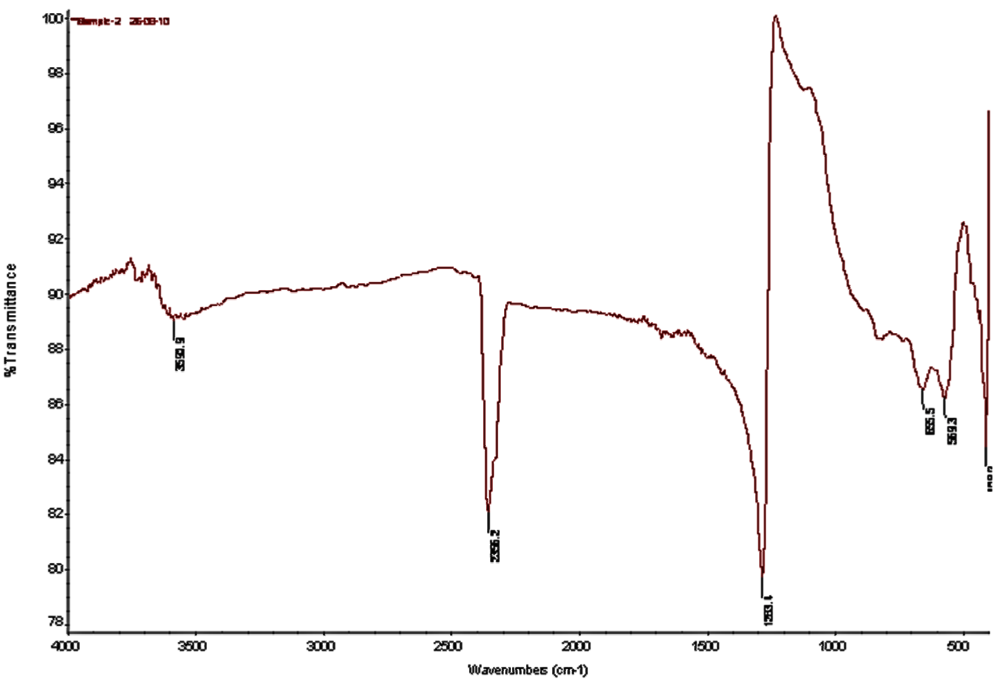

Figure 3.6 Fourier Transform spectrum for CdO Nanowires/Nanobelts

Spray pyrolysed CdO was characterized by FTIR analysis [Thermo electron corporation-make, NEXUS 670-model] and corresponding spectrum is shown in figure (3.6.)

The sharp peak at 1283.4 and comparatively two small peaks corresponds to the presence of Cadmium and Oxygen in the sample. In The FTIR spectrum the strong absorption in the range of 1283 to1641 and the other couple of peaks in the range of 559 and 6655. The weak absorption at 1641 is also found in the FTIR spectrum. The above information gives the presence of Cadmium reacting with Oxygen in the air during the time of preparing CdO by Spray Pyrolysis. From the FTIR spectrum it is conformed that presence of Cadmium and Oxygen in the range between 1641 to 1283 cm^{-1} respectively.

4. CONCLUSION

The XRD analysis shows that CdO Nanowires/Nanobelts crystal structure. The diffraction peaks indicates that resulting products have CdO phase having plane 100 at angle 2θ=33.06, 38.40, 69.30. The FTIR spectrum conformed the presence of Cadmium and Oxygen very strongly. The SEM picture shows the presence of Nanowires/Nanobelts in three different regions with three different Nanowires/ Nanobelts size. Even the size of the Nanowires/Nanobelts some what less than 10 nms it is possible to bring a Nanowires/ Nanobelts of size less than 10 nms by Spray Pyrolysis/sol-gel techniques. Also very limited articles are available on CdO nanowires/nanobelts. So an attempt has been made to fabricate CdO nanowires /nanobelts using spray pyrolysis. The formation process of Nanowires/Nanobelts from Cadmium Chloride Spray Pyrolysis is successfully established the Cadmium Oxide Nanowires/Nanobelts are Nanometric.

5. REFERENCES

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